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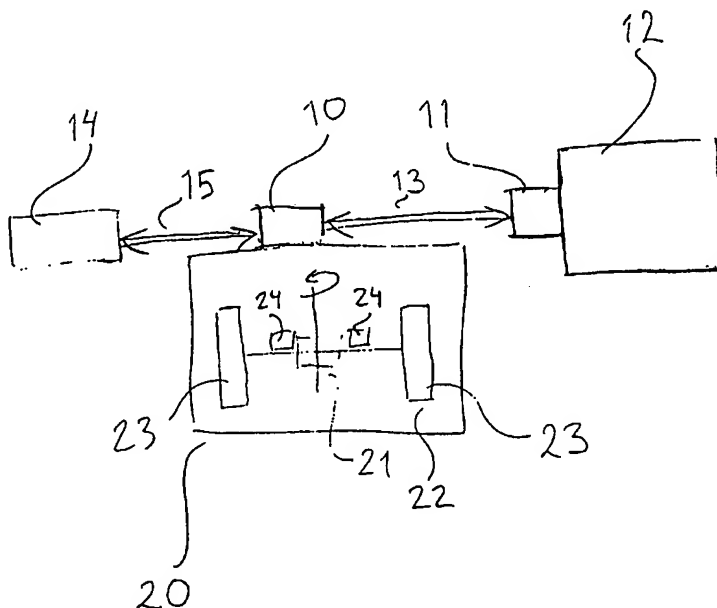
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(54) Title: SYSTEM FOR STORAGE OF POWER



(57) Abstract: The invention relates to a power storage system intended to transmit power to and from a driving system of a vehicle. A power storage having a stator provided with two windings and at least one rotor provided with a magnetic-flux generating device is comprised. The rotor is connected to a flywheel intended for storage of energy. The two windings of the stator are arranged for high and low voltage, respectively. The power storage is arranged to transmit power to and from the electric apparatus as well as store energy transmitted from the electric apparatus in the flywheel.

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#### Declarations under Rule 4.17:

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MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, *ARIPO patent* (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), *Eurasian patent* (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), *European patent* (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), *OAPI patent* (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

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System for storage of power.**Technical Field of the Invention**

The present invention relates to a power storage system intended to store  
5 and transmit power to and from a driving system of a vehicle. The system comprises a power storage having a stator provided with winding and at least one rotor provided with a magnetic-flux generating device. The rotor is connected to at least one flywheel intended for storage of energy in the form of kinetic energy in at least one rotary mass. The driving system comprises an electric apparatus, the power  
10 storage being arranged to transmit power to and from said electric apparatus.

**Background Art**

Power storage systems having a flywheel that is charged by a driving object and subsequently serves as source of power for, e. g., an electric motor is used,  
15 *inter alia*, in driving systems such as a driveline of a vehicle. However, known systems are limited, the energy storage capacity is limited by many factors such as the weight of the system, security requirements, the availability of suitable materials as well as the availability of suitable driving systems for the recharging of the flywheel and for the discharging of the same. In a driveline in a hybrid vehicle,  
20 an energy storage is found, which, e.g., may be a battery and/or a fuel tank, an electric drive motor and/or an internal combustion engine.

To be able to make use of the energy at retardation of a vehicle, for instance an automobile or a train, a fast system that manages to transmit and store high powers is required. The stronger the retardation is, the higher power the  
25 system has to be able to handle in order to make use of the energy.

A known system for storage of kinetic energy is shown in US 5 931 249. The system described according to the document comprises a flywheel, intended for accumulation and discharging of energy, respectively, which is coupled to an electric apparatus operating as motor and generator, respectively, depending on  
30 whether energy is fed to or from the flywheel. When the system is used in a vehicle, during shorter periods of time the vehicle may be driven from the flywheel. The flywheel rotates at a high speed in vacuum. Together with the system described, high currents are required, which results in high losses if high power is to be handled. Thus, the known system is not suitable for high powers.

Today's batteries are limited in respect of the power that they manage to carry. This entails that the charging time for battery-powered vehicles generally amounts to several hours. A battery-powered vehicle cannot be driven more than a limited range before the vehicle has to be brought to a recharging station and  
5 there be recharged during a relatively long time before the vehicle again has a certain range, frequently in the range of 100 km.

### ***Brief Description of the Invention***

The invention according to the present application is intended to provide a  
10 power storage system intended for storage and discharging of energy in a driving system of a vehicle that solves the above-described problems. The system comprises a power storage having a stator provided with two windings and a rotor provided with a magnetic-flux generating device. The first winding of the stator is intended for low voltage for the transmission of energy of low power, while the  
15 second winding is intended for high voltage for the transmission of high power. The rotor is connected to a flywheel intended for storage of kinetic energy in at least one rotary mass. The power storage system is arranged to transmit power in both directions between the power storage and an electric apparatus comprised in the driving system. By choosing to provide the stator with a high-voltage winding,  
20 ing, very high power can be transmitted in both directions in the system. Thanks to this, the system becomes very fast and manages to handle the power that is developed during fast dynamical processes.

With low voltage is meant voltage below 380 V and with high voltage is meant voltage above 380 V.

25 In a preferred embodiment, said first winding is arranged to operate at a voltage that is in the interval of 6–50 V.

In a further, preferred embodiment, said second winding is arranged to operate at a voltage that is in the interval of 1–24 kV.

In a further, preferred embodiment, at least one of said windings comprises  
30 a conductor surrounded by a first semiconducting layer, said first semiconducting layer is then surrounded by a layer of fixed insulation, said first layer of fixed insulation is then surrounded by a second semiconducting layer. By means of a winding having this type of insulation system, a very high power can be transmitted.

In a further, preferred embodiment, in said driving system an energy storage is comprised, which may be a battery, that is connected with the electric apparatus of the driving system. Power may be transmitted from the power storage to the energy storage and vice versa. By arranging the windings in the stator in such a way that they are controlled entirely independently of each other, at every instant a battery in a driving system can be utilized in an optimal way regarding discharging and recharging. In a hybrid vehicle being driven in the position of battery operation thereof, i.e. when the fuel engine of the vehicle is not used, for instance during driving of a bus in an urban environment, fast processes that require high power can be regulated via the power storage/flywheel while continuous energy is fed to the driving system via the battery of the vehicle during battery operation. Thus, at fast and strong retardations energy is fed to the flywheel for accumulation and is fed out therefrom when power requirement is at hand, as, for instance, at variations of torque or demands of quick acceleration of the vehicle.

Further, by the fact that both windings of the stator are intended to operate at high and low voltage, respectively, the system enables energy to be fed very fast to and from the flywheel via the high-voltage winding, as energy to and from the battery is fed with appropriate voltage via the low-voltage winding of the stator. The windings operate entirely independently of each other, and therefore the load of the battery can be adapted in a way that is favourable to the condition and service life of the battery. Then, at every instant the battery can operate in a way being appropriate to the battery, while fast and power-demanding variations of operation such as accelerations and strong retardations, are managed via the flywheel and the high-voltage winding of the stator, which enables quick transmission of energy in a very short time to and from the flywheel of the system.

In a preferred embodiment, the flywheel is charged with energy that has been transmitted from an external source. In a battery-powered vehicle, by utilizing a driving system having a power storage system according to the present invention, the battery of the vehicle can, on one hand, be recharged in a conventional way at a recharging station, and the flywheel can, on the other hand, be charged maximally with energy. During operation, the energy accumulated in the flywheel may then be used for the propulsion of the vehicle, thereby increasing the range of the vehicle considerable, or alternatively the energy may be used for continued

recharging of the battery of the vehicle. In this way, the battery may be charged continuously during a longer period of time, while the downtime at the recharging station yet becomes considerable shorter.

In a preferred embodiment, said magnetic-flux generating device in the  
5 rotor comprises permanent magnets.

In another preferred embodiment, said magnetic-flux generating device in the rotor comprises a squirrel cage winding.

In a further, preferred embodiment, said rotor is mounted with magnetic bearings.

10 The rotor is, in a further, preferred embodiment, mounted with both magnetic bearings and sliding bearings.

In a further, preferred embodiment, said stator is air-gap wound.

In a further, preferred embodiment said power storage is gyro suspended. By choosing a gyro suspended power storage, the driving properties of the vehicle  
15 will only be affected on a small scale.

In a further, preferred embodiment, said flywheel comprises at least two rotary masses that are arranged to rotate in opposite directions of rotation in relation to each other. By using counter-rotating masses, the forces that arise in the system at rotation of the same are minimised.

20 In a further, preferred embodiment, said rotor comprises a first core, a second core as well as a third core. The first winding is arranged in the air gap between the first and the second core and the second winding is arranged in the air gap between the second and the third the core. By means of this configuration, the first and the second winding are magnetically disconnected from each other  
25 and can thereby operate entirely independently of each other.

The system according to the present invention may be used together with any vehicle, for instance automobile, train, aeroplane, boat. The above-described system has high efficiency, above 90 %, and reacts very fast, in the range of a few milliseconds. The system is compact, robust and durable, which is a prerequisite  
30 for use in severe environment, which is the case in most types of vehicles. The system manages to generate and absorb high powers.

### ***Brief Description of the Drawings***

Fig. 1 shows a driving system of a vehicle having a power storage system according to the present invention.

Fig. 2 shows a further driving system of a vehicle having a power storage system according to the present invention.

5 Fig. 3 shows a power storage that is comprised in the system according to the present invention.

Fig. 4 shows an embodiment of the stator comprised in the power storage.

### ***Detailed Description of Preferred Embodiments***

10 Fig. 1 shows a power storage system according to the present invention. A power storage 20 having a stator 24 and a rotor 21 that is connected to a flywheel 22 is – via a first converter 10, a direct current transmission 13 and a second converter 11 – arranged to transmit power to and from an electric apparatus 12. The flywheel 22 comprises a rotary mass 23. When power is transmitted from the  
15 electric apparatus 12 to the power storage 20, which, for instance, is the case at retardation of an electrically driven vehicle, the apparatus 12 operates as generator and power is transmitted from the apparatus 12 via the converter 11, the direct current transmission 13 and the converter 10 to a winding (not shown in figure) comprised in the stator 24 and is then stored in the flywheel 22 in the form  
20 of kinetic energy in the rotary mass 23. The kinetic energy stored in the rotary mass 23 may subsequently, if required, be correspondingly transmitted to the electric apparatus. Then the electric apparatus operates as motor. This system may be used in the driveline of a vehicle, and the power storage 20 is then used both as power buffer and energy buffer. The stator comprises two windings, with  
25 the first winding being intended for low voltage for the transmission of energy of low power, while the second winding is intended for high voltage for the transmission of high power. The stator's winding in which high power is transmitted is arranged to operate at high voltage over 380 V, preferably in the interval of 1–24 kV. By said arrangement, very high power can be transmitted to and from the  
30 power storage 20. Thanks to this, the system manages to handle the high powers that arise at, for instance, strong retardations.

Fig. 2 shows a system having an energy storage 14 that may be a battery, a fuel cell, or other chemically stored energy such as a fuel tank of an internal combustion engine, and a power storage 20 comprising a stator 24 and a rotor 21

connected to a flywheel 22 having a rotary mass 23. The stator 24 is provided with a first and a second winding (not shown in figure). The respective windings are arranged to operate at low voltage and at high voltage, respectively. With low voltage is meant voltage lower than 380 V and with high voltage is meant voltage higher than 380 V. The rotor 21 is provided with a suitable magnetic-flux generating device such as, for instance, permanent magnets or an induction winding. The flywheel 22 is intended for accumulation and quick transmission of power to and from the driving system. Further, the power storage system comprises two converters 10 and 11 having an intermediate direct current transmission 13. One of the converters, converter 11, is arranged in connection with an electric apparatus 12. As in the system shown in figure 1, the electric apparatus 12 operates either as motor or as generator depending on present mode of operation. At retardation of a vehicle provided with this system, the apparatus 12 operates as generator and the generated power is transmitted via the converter 11 and the direct current transmission 13, which can operate at high voltage as, e. g., 1.2 kV, via the converter 10 to the high-voltage winding of the stator and further to the power storage 20, where the energy is stored in the form of kinetic energy in the rotary mass 23 of the flywheel. By the fact that the power is transmitted at high voltage from the high-voltage winding of the stator, high powers, such as braking power at strong retardation of a vehicle, can be made use of and stored. The power accumulated in the flywheel may subsequently be used in fast processes, such as variations of torque or quick acceleration of a vehicle, when the energy from the flywheel can be brought back very fast to the driving system via the high-voltage winding of the stator. Alternatively, in the case where the energy storage 14 consists of a battery, the energy stored in the flywheel may be used to recharge the battery. Then, the energy is transmitted at low power and low voltage to the battery via the low-voltage winding of the stator.

Fig. 3 shows a power storage of the type that is comprised in both of the above-described systems according to figure 1 and 2. The rotor 21 is mounted with a journal bearing 25 and a guide bearing 26, respectively. The bearings may be conventional bearings or magnetic or a combination of magnetic bearings and sliding bearings. The rotor 21 is connected to a flywheel 22 provided with a rotary mass 23. Further, the power storage comprises a stator 24 provided with a first and a second winding (not shown in figure). During operation, power is transmit-

ted between the stator 24 and the rotor 21, and thereby the flywheel 22 having the rotary mass 23, via one of the windings of the stator .

Fig. 4 shows an embodiment of an air-gap wound stator 24. A first winding 31 is arranged between first and second cores 32, 33 arranged in the rotor. A  
5 second winding 31 is arranged between the second core 33 and a third core 34 arranged in the rotor. By means of this configuration, the first winding 30 and the second winding 31 are magnetically disconnected from each other and can, thereby, be controlled entirely independently of each other. The arrows 35 show the direction of the magnetic field.

10 The stator and rotor of the power storage may be arranged to operate with either radially or axially directed magnetic flux.

The invention is not limited to the above embodiments given as examples, but may be made as modifications within the scope of the general idea according to the invention described in the appended claims.

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## CLAIMS

1. Power storage system, intended to transmit power to and from a driving system of a vehicle, said driving system comprising at least one electric apparatus (12),  
5 comprising a power storage (20) having a stator-provided winding (24) and at least one rotor (21) provided with a magnetic-flux generating device, said rotor (21) being connected to at least one flywheel (22) intended for storage of energy in the form of kinetic energy in at least one rotary mass (23),  
10 said power storage (20) being arranged to transmit power to and from said electric apparatus (12),  
**characterized in**  
that said stator (24) comprises at least a first winding (30) arranged to operate at low voltage as well as a second winding (31) arranged to operate at high voltage,  
15 said first and second windings being arranged to operate independently of each other.
2. Power storage system according to the preceding claim,  
**characterized in**  
20 that at least one energy storage (14) is comprised, which energy storage is connected with said electric apparatus (12), said power storage (20) being arranged to transmit power to and from said energy storage (14).
3. Power storage system according to any one of claims 1 or 2,  
25 **characterized in**  
that said power storage (20) is arranged to receive power that has been transmitted from an external source.
4. Power storage system according to any one of the preceding claims,  
30 **characterized in**  
that said magnetic-flux generating device in the rotor (21) comprises permanent magnets.
5. Power storage system according to any one of claims 1–3,

**characterized in**

that said magnetic-flux generating device in the rotor (21) comprises a squirrel cage winding.

- 5        6.        Power storage system according to any one of the preceding claims,  
**characterized in**  
that said rotor (21) is mounted with magnetic bearings.

7.        Power storage system according to claim 6,  
10 **characterized in**  
that said rotor (21) also is mounted with sliding bearings.

8.        Power storage system according to any one of the preceding claims,  
**characterized in**  
15 that said first winding (30) is arranged to operate at a voltage that is lower than  
380 V.

9.        Power storage system according to claim 8,  
**characterized in**  
20 that said first winding (30) is arranged to operate at a voltage that is in the interval  
of 6–50 V.

10.       Power storage system according to any one of the preceding claims,  
**characterized in**  
25 that said second winding (31) is arranged to operate at a voltage that is higher  
than 380 V.

11.       Power storage system according to claim 10,  
**characterized in**  
30 that said second winding (31) is arranged to operate at a voltage that is in the  
interval of 1–24 kV.

12.       Power storage system according to any one of the preceding claims,  
**characterized in**

that said stator (24) is air-gap wound.

13. Power storage system according to any one of the preceding claims,  
**characterized in**

5 that said power storage (20) is gyro suspended.

14. Power storage system according to any one of the preceding claims,  
**characterized in**

10 that said flywheel (22) comprises two rotary masses (23) that are arranged to  
rotate in opposite directions of rotation in relation to each other.

15. Power storage system according to any one of the preceding claims,  
**characterized in**

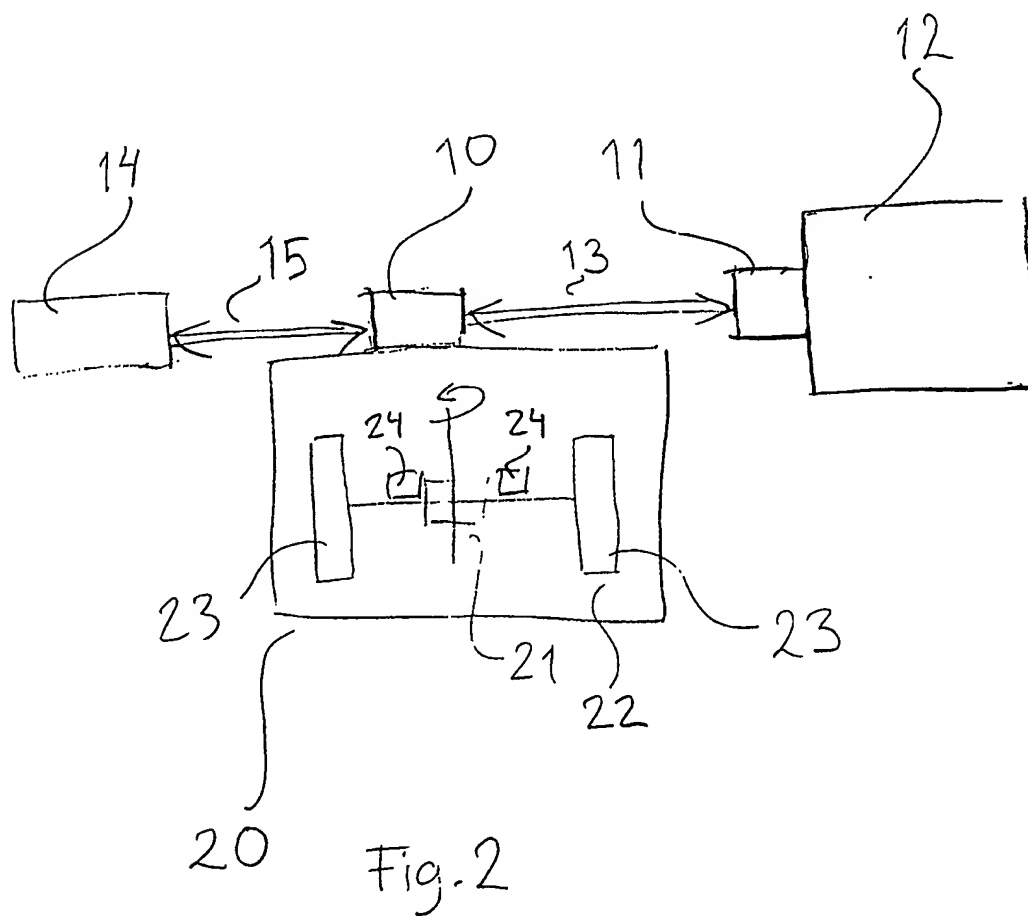
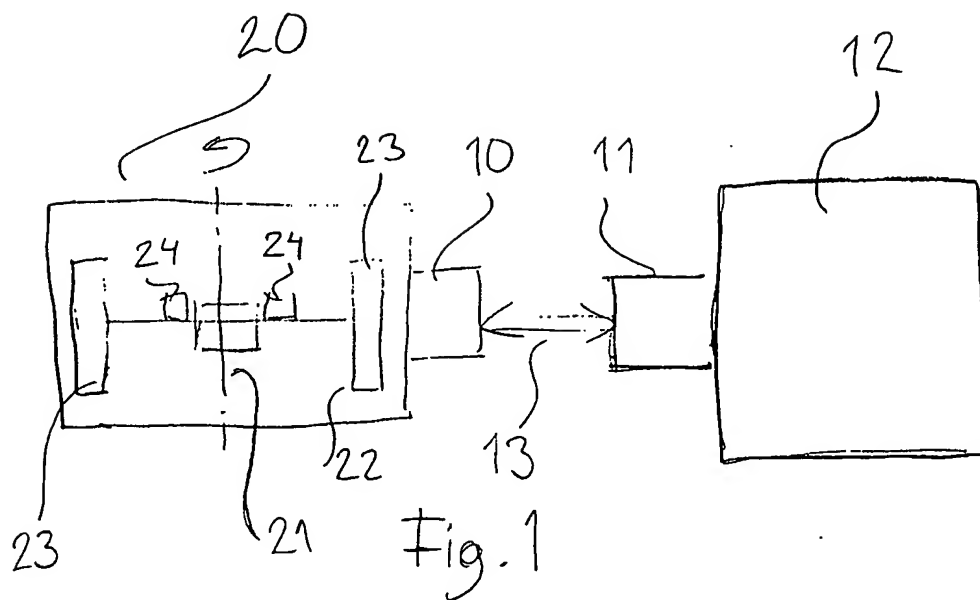
15 that at least one of said windings (30, 31) comprises a conductor surrounded by a  
first semiconducting layer, said first semiconducting layer is then surrounded by a  
layer of fixed insulation, said first layer of fixed insulation is then surrounded by a  
second semiconducting layer.

16. Power storage system according to any one of the preceding claims,  
20 **characterized in**

that said rotor (24) comprises a first core (32), a second core (33) as well as a  
third core (34), the first winding (30) of the stator being arranged between said first  
(32) and said second (33) core and the second winding (31) of the stator being  
arranged between said second (33) and said third (34) core.

25

17. Vehicle provided with a power storage system according to any one of  
claims 1–16.



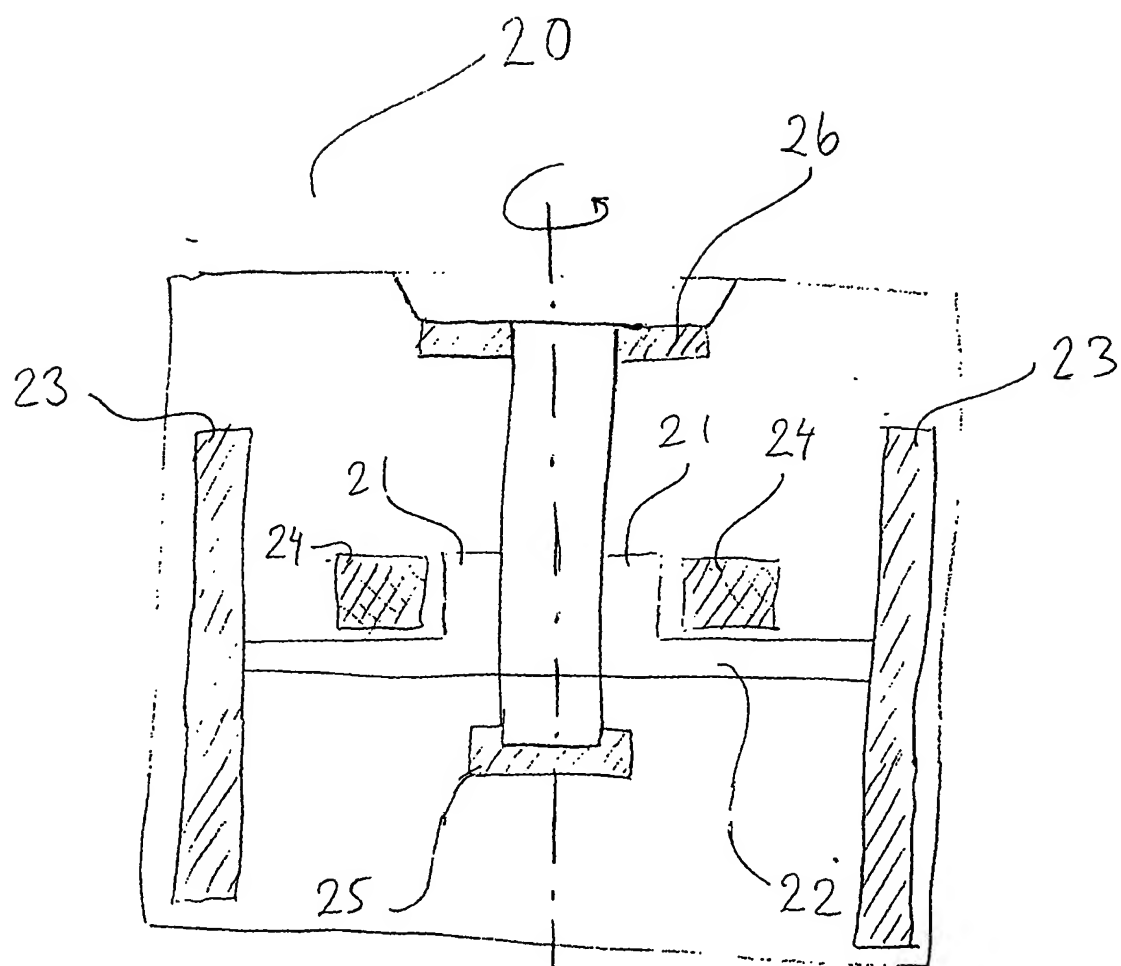


Fig. 3

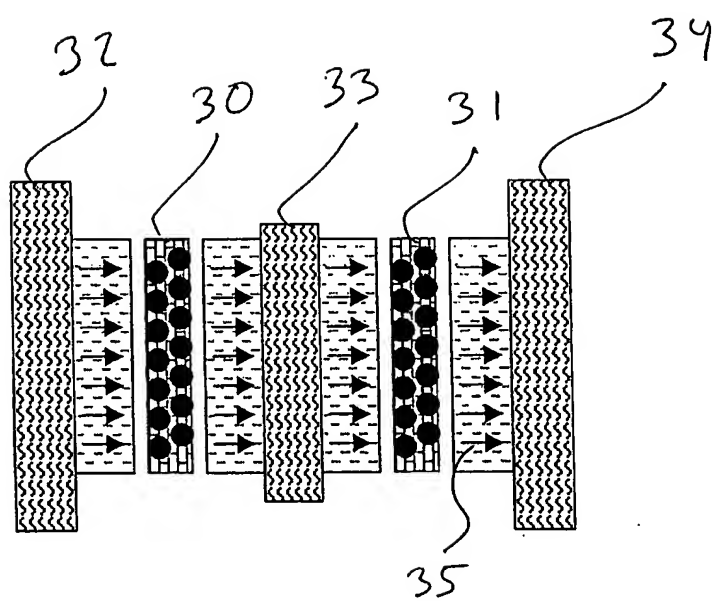


Fig. 4

## INTERNATIONAL SEARCH REPORT

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## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B60K 6/06, H02K 7/02  
According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H02K, B60K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ, INSPEC

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 19718480 A1 (SIEMENS AG), 6 November 1997 (06.11.1997), column 1, line 3 - column 7, line 36, figure 1, abstract  --	1-17
A	US 5124605 A (JACK G. BITTERLY ET AL), 23 June 1992 (23.06.1992), figure 2, abstract  --	1-17
A	US 4163187 A (SERGE J.H. THOMAS), 31 July 1979 (31.07.1979), column 1, line 58 - column 2, line 10, figures 2,3  --	1-17

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
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Date of the actual completion of the international search 2 February 2004	Date of mailing of the international search report 17 -02- 2004
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 8200117 A1 ("EKLAMA" SCHALTANLAGENBAU-GESELLSCHAFT M.B.H.), 21 January 1982 (21.01.1982), abstract, see figure 1 and esp. fig 3  --	1-17
A	EP 0437266 A2 (MAGNET-MOTOR GESELLSCHAFT FÜR MAGNETMOTORISCHE TEKNIK MBH), 10 January 1991 (10.01.1991), figure 1, abstract, see whole document  --	1-17
A	FR 2806979 A1 (RENAULT), 5 October 2001 (05.10.2001), figure 1, abstract  -- -----	1-17

## INTERNATIONAL SEARCH REPORT

Information on patent family members

24/12/2003

International application No.

PCT/SE 2003/001780

DE	19718480	A1	06/11/1997	NONE		
US	5124605	A	23/06/1992	AT	161127 T	15/12/1997
				AU	664984 B	14/12/1995
				AU	683193 B	30/10/1997
				AU	1232692 A	17/08/1992
				AU	4810296 A	20/06/1996
				BR	9205459 A	05/04/1994
				CA	2100260 A	12/07/1992
				CZ	9301363 A	15/02/1995
				DE	69223501 D	00/00/0000
				EP	0566678 A,B	27/10/1993
				JP	6506754 T	28/07/1994
				SK	72593 A	10/11/1993
				US	5268608 A	07/12/1993
				US	5466977 A	14/11/1995
				US	5729903 A	24/03/1998
				US	6138527 A	31/10/2000
				WO	9212566 A	23/07/1992
US	4163187	A	31/07/1979	BR	7600032 A	03/08/1976
				CA	1081776 A	15/07/1980
				CA	1112298 A	10/11/1981
				DE	2600035 A,B,C	15/07/1976
				DE	2660017 B	15/03/1979
				ES	444161 A	01/08/1977
				FR	2297513 A,B	06/08/1976
				GB	1513270 A	07/06/1978
				IT	1052906 B	31/08/1981
				JP	51095209 A	20/08/1976
				JP	56171570 U	18/12/1981
				SE	419922 B,C	31/08/1981
				SE	7513983 A	12/07/1976
				ZA	7600124 A	30/11/1977
WO	8200117	A1	21/01/1982	DE	3152165 D	00/00/0000
				JP	57501159 T	01/07/1982
EP	0437266	A2	10/01/1991	SE	0437266 T3	
				AT	145368 T	15/12/1996
				DE	4000678 A	18/07/1991
				DE	59108349 D	00/00/0000
				DK	437266 T	28/04/1997
FR	2806979	A1	05/10/2001	NONE		

## POWER STORAGE SYSTEM

### *Technical Field of the Invention*

The present invention relates to a power storage system intended to store  
5 and transmit power to and from a driving system of a vehicle. The system comprises a power storage having a stator provided with winding and at least one rotor provided with a magnetic-flux generating device. The rotor is connected to at least one flywheel intended for storage of energy in the form of kinetic energy in at least one rotary mass. The driving system comprises an electric apparatus, the power  
10 storage being arranged to transmit power to and from said electric apparatus.

### *Background Art*

Power storage systems having a flywheel that is charged by a driving object and subsequently serves as source of power for, e. g., an electric motor is used,  
15 *inter alia*, in driving systems such as a driveline of a vehicle. However, known systems are limited, the energy storage capacity is limited by many factors such as the weight of the system, security requirements, the availability of suitable materials as well as the availability of suitable driving systems for the recharging of the flywheel and for the discharging of the same. In a driveline in a hybrid vehicle,  
20 an energy storage is found, which, e.g., may be a battery and/or a fuel tank, an electric drive motor and/or an internal combustion engine.

To be able to make use of the energy at retardation of a vehicle, for instance an automobile or a train, a fast system that manages to transmit and store high powers is required. The stronger the retardation is, the higher power the  
25 system has to be able to handle in order to make use of the energy.

A known system for storage of kinetic energy is shown in US 5 931 249. The system described according to the document comprises a flywheel, intended for accumulation and discharging of energy, respectively, which is coupled to an electric apparatus operating as motor and generator, respectively, depending on  
30 whether energy is fed to or from the flywheel. When the system is used in a vehicle, during shorter periods of time the vehicle may be driven from the flywheel. The flywheel rotates at a high speed in vacuum. Together with the system described, high currents are required, which results in high losses if high power is to be handled. Thus, the known system is not suitable for high powers.

Today's batteries are limited in respect of the power that they manage to carry. This entails that the charging time for battery-powered vehicles generally amounts to several hours. A battery-powered vehicle cannot be driven more than a limited range before the vehicle has to be brought to a recharging station and  
 5 there be recharged during a relatively long time before the vehicle again has a certain range, frequently in the range of 100 km.

### ***Brief Description of the Invention***

The invention according to the present application is intended to provide a  
 10 power storage system intended for storage and discharging of energy in a driving system of a vehicle that solves the above-described problems. The system comprises a power storage having a stator provided with two windings and a rotor provided with a magnetic-flux generating device. The first winding of the stator is intended for low voltage for the transmission of energy of low power, while the  
 15 second winding is intended for high voltage for the transmission of high power. The rotor is connected to a flywheel intended for storage of kinetic energy in at least one rotary mass. The power storage system is arranged to transmit power in both directions between the power storage and an electric apparatus comprised in the driving system. By choosing to provide the stator with a high-voltage wind-  
 20 ing, very high power can be transmitted in both directions in the system. Thanks to this, the system becomes very fast and manages to handle the power that is developed during fast dynamical processes.

With low voltage is meant voltage below 380 V and with high voltage is meant voltage above 380 V.

25 In a preferred embodiment, said first winding is arranged to operate at a voltage that is in the interval of 6–50 V.

In a further, preferred embodiment, said second winding is arranged to operate at a voltage that is in the interval of 1–24 kV.

In a further, preferred embodiment, at least one of said windings comprises  
 30 a conductor surrounded by a first semiconducting layer, said first semiconducting layer is then surrounded by a layer of fixed insulation, said first layer of fixed insulation is then surrounded by a second semiconducting layer. By means of a winding having this type of insulation system, a very high power can be transmitted.

In a further, preferred embodiment, in said driving system an energy storage is comprised, which may be a battery, that is connected with the electric apparatus of the driving system. Power may be transmitted from the power storage to the energy storage and vice versa. By arranging the windings in the stator in such a way that they are controlled entirely independently of each other, at every instant a battery in a driving system can be utilized in an optimal way regarding discharging and recharging. In a hybrid vehicle being driven in the position of battery operation thereof, i.e. when the fuel engine of the vehicle is not used, for instance during driving of a bus in an urban environment, fast processes that require high power can be regulated via the power storage/flywheel while continuous energy is fed to the driving system via the battery of the vehicle during battery operation. Thus, at fast and strong retardations energy is fed to the flywheel for accumulation and is fed out therefrom when power requirement is at hand, as, for instance, at variations of torque or demands of quick acceleration of the vehicle.

Further, by the fact that both windings of the stator are intended to operate at high and low voltage, respectively, the system enables energy to be fed very fast to and from the flywheel via the high-voltage winding, as energy to and from the battery is fed with appropriate voltage via the low-voltage winding of the stator. The windings operate entirely independently of each other, and therefore the load of the battery can be adapted in a way that is favourable to the condition and service life of the battery. Then, at every instant the battery can operate in a way being appropriate to the battery, while fast and power-demanding variations of operation such as accelerations and strong retardations, are managed via the flywheel and the high-voltage winding of the stator, which enables quick transmission of energy in a very short time to and from the flywheel of the system.

In a preferred embodiment, the flywheel is charged with energy that has been transmitted from an external source. In a battery-powered vehicle, by utilizing a driving system having a power storage system according to the present invention, the battery of the vehicle can, on one hand, be recharged in a conventional way at a recharging station, and the flywheel can, on the other hand, be charged maximally with energy. During operation, the energy accumulated in the flywheel may then be used for the propulsion of the vehicle, thereby increasing the range of the vehicle considerable, or alternatively the energy may be used for continued

recharging of the battery of the vehicle. In this way, the battery may be charged continuously during a longer period of time, while the downtime at the recharging station yet becomes considerable shorter.

In a preferred embodiment, said magnetic-flux generating device in the  
5 rotor comprises permanent magnets.

In another preferred embodiment, said magnetic-flux generating device in the rotor comprises a squirrel cage winding.

In a further, preferred embodiment, said rotor is mounted with magnetic bearings.

10 The rotor is, in a further, preferred embodiment, mounted with both magnetic bearings and sliding bearings.

In a further, preferred embodiment, said stator is air-gap wound.

In a further, preferred embodiment said power storage is gyro suspended. By choosing a gyro suspended power storage, the driving properties of the vehicle  
15 will only be affected on a small scale.

In a further, preferred embodiment, said flywheel comprises at least two rotary masses that are arranged to rotate in opposite directions of rotation in relation to each other. By using counter-rotating masses, the forces that arise in the system at rotation of the same are minimised.

20 In a further, preferred embodiment, said rotor comprises a first core, a second core as well as a third core. The first winding is arranged in the air gap between the first and the second core and the second winding is arranged in the air gap between the second and the third the core. By means of this configuration, the first and the second winding are magnetically disconnected from each other  
25 and can thereby operate entirely independently of each other.

The system according to the present invention may be used together with any vehicle, for instance automobile, train, aeroplane, boat. The above-described system has high efficiency, above 90 %, and reacts very fast, in the range of a few milliseconds. The system is compact, robust and durable, which is a prerequisite  
30 for use in severe environment, which is the case in most types of vehicles. The system manages to generate and absorb high powers.

### ***Brief Description of the Drawings***

Fig. 1 shows a driving system of a vehicle having a power storage system according to the present invention.

Fig. 2 shows a further driving system of a vehicle having a power storage system according to the present invention.

5 Fig. 3 shows a power storage that is comprised in the system according to the present invention.

Fig. 4 shows an embodiment of the stator comprised in the power storage.

### ***Detailed Description of Preferred Embodiments***

10 Fig. 1 shows a power storage system according to the present invention. A power storage 20 having a stator 24 and a rotor 21 that is connected to a flywheel 22 is – via a first converter 10, a direct current transmission 13 and a second converter 11 – arranged to transmit power to and from an electric apparatus 12. The flywheel 22 comprises a rotary mass 23. When power is transmitted from the  
15 electric apparatus 12 to the power storage 20, which, for instance, is the case at retardation of an electrically driven vehicle, the apparatus 12 operates as generator and power is transmitted from the apparatus 12 via the converter 11, the direct current transmission 13 and the converter 10 to a winding (not shown in figure) comprised in the stator 24 and is then stored in the flywheel 22 in the form  
20 of kinetic energy in the rotary mass 23. The kinetic energy stored in the rotary mass 23 may subsequently, if required, be correspondingly transmitted to the electric apparatus. Then the electric apparatus operates as motor. This system may be used in the driveline of a vehicle, and the power storage 20 is then used both as power buffer and energy buffer. The stator comprises two windings, with  
25 the first winding being intended for low voltage for the transmission of energy of low power, while the second winding is intended for high voltage for the transmission of high power. The stator's winding in which high power is transmitted is arranged to operate at high voltage over 380 V, preferably in the interval of 1–24 kV. By said arrangement, very high power can be transmitted to and from the  
30 power storage 20. Thanks to this, the system manages to handle the high powers that arise at, for instance, strong retardations.

Fig. 2 shows a system having an energy storage 14 that may be a battery, a fuel cell, or other chemically stored energy such as a fuel tank of an internal combustion engine, and a power storage 20 comprising a stator 24 and a rotor 21

connected to a flywheel 22 having a rotary mass 23. The stator 24 is provided with a first and a second winding (not shown in figure). The respective windings are arranged to operate at low voltage and at high voltage, respectively. With low voltage is meant voltage lower than 380 V and with high voltage is meant voltage higher than 380 V. The rotor 21 is provided with a suitable magnetic-flux generating device such as, for instance, permanent magnets or an induction winding. The flywheel 22 is intended for accumulation and quick transmission of power to and from the driving system. Further, the power storage system comprises two converters 10 and 11 having an intermediate direct current transmission 13. One of the converters, converter 11, is arranged in connection with an electric apparatus 12. As in the system shown in figure 1, the electric apparatus 12 operates either as motor or as generator depending on present mode of operation. At retardation of a vehicle provided with this system, the apparatus 12 operates as generator and the generated power is transmitted via the converter 11 and the direct current transmission 13, which can operate at high voltage as, e. g., 1.2 kV, via the converter 10 to the high-voltage winding of the stator and further to the power storage 20, where the energy is stored in the form of kinetic energy in the rotary mass 23 of the flywheel. By the fact that the power is transmitted at high voltage from the high-voltage winding of the stator, high powers, such as braking power at strong retardation of a vehicle, can be made use of and stored. The power accumulated in the flywheel may subsequently be used in fast processes, such as variations of torque or quick acceleration of a vehicle, when the energy from the flywheel can be brought back very fast to the driving system via the high-voltage winding of the stator. Alternatively, in the case where the energy storage 14 consists of a battery, the energy stored in the flywheel may be used to recharge the battery. Then, the energy is transmitted at low power and low voltage to the battery via the low-voltage winding of the stator.

Fig. 3 shows a power storage of the type that is comprised in both of the above-described systems according to figure 1 and 2. The rotor 21 is mounted with a journal bearing 25 and a guide bearing 26, respectively. The bearings may be conventional bearings or magnetic or a combination of magnetic bearings and sliding bearings. The rotor 21 is connected to a flywheel 22 provided with a rotary mass 23. Further, the power storage comprises a stator 24 provided with a first and a second winding (not shown in figure). During operation, power is transmit-

ted between the stator 24 and the rotor 21, and thereby the flywheel 22 having the rotary mass 23, via one of the windings of the stator .

Fig. 4 shows an embodiment of an air-gap wound stator 24. A first winding 31 is arranged between first and second cores 32, 33 arranged in the rotor. A  
5 second winding 31 is arranged between the second core 33 and a third core 34 arranged in the rotor. By means of this configuration, the first winding 30 and the second winding 31 are magnetically disconnected from each other and can, thereby, be controlled entirely independently of each other. The arrows 35 show the direction of the magnetic field.

10 The stator and rotor of the power storage may be arranged to operate with either radially or axially directed magnetic flux.

The invention is not limited to the above embodiments given as examples, but may be made as modifications within the scope of the general idea according to the invention described in the appended claims.

## CLAIMS

1. Power storage system, intended to transmit power to and from a driving system of a vehicle, said driving system comprising at least one electric apparatus (12),  
5 comprising a power storage (20) having a stator-provided winding (24) and at least one rotor (21) provided with a magnetic-flux generating device, said rotor (21) being connected to at least one flywheel (22) intended for storage of energy in the form of kinetic energy in at least one rotary mass (23),  
10 said power storage (20) being arranged to transmit power to and from said electric apparatus (12),  
**characterized in**  
that said stator (24) comprises at least a first winding (30) arranged to operate at low voltage as well as a second winding (31) arranged to operate at high voltage,  
15 said first and second windings being arranged to operate independently of each other.
2. Power storage system according to the preceding claim,  
**characterized in**  
20 that at least one energy storage (14) is comprised, which energy storage is connected with said electric apparatus (12), said power storage (20) being arranged to transmit power to and from said energy storage (14).
3. Power storage system according to any one of claims 1 or 2,  
25 **characterized in**  
that said power storage (20) is arranged to receive power that has been transmitted from an external source.
4. Power storage system according to any one of the preceding claims,  
30 **characterized in**  
that said magnetic-flux generating device in the rotor (21) comprises permanent magnets.
5. Power storage system according to any one of claims 1–3,

**characterized in**

that said magnetic-flux generating device in the rotor (21) comprises a squirrel cage winding.

- 5        6.        Power storage system according to any one of the preceding claims,  
**characterized in**  
that said rotor (21) is mounted with magnetic bearings.

7.        Power storage system according to claim 6,  
10 **characterized in**  
that said rotor (21) also is mounted with sliding bearings.

8.        Power storage system according to any one of the preceding claims,  
**characterized in**  
15 that said first winding (30) is arranged to operate at a voltage that is lower than  
380 V.

9.        Power storage system according to claim 8,  
**characterized in**  
20 that said first winding (30) is arranged to operate at a voltage that is in the interval  
of 6–50 V.

10.       Power storage system according to any one of the preceding claims,  
**characterized in**  
25 that said second winding (31) is arranged to operate at a voltage that is higher  
than 380 V.

11.       Power storage system according to claim 10,  
**characterized in**  
30 that said second winding (31) is arranged to operate at a voltage that is in the  
interval of 1–24 kV.

12.       Power storage system according to any one of the preceding claims,  
**characterized in**

that said stator (24) is air-gap wound.

13. Power storage system according to any one of the preceding claims,  
**characterized in**

5 that said power storage (20) is gyro suspended.

14. Power storage system according to any one of the preceding claims,  
**characterized in**

that said flywheel (22) comprises two rotary masses (23) that are arranged to  
10 rotate in opposite directions of rotation in relation to each other.

15. Power storage system according to any one of the preceding claims,  
**characterized in**

that at least one of said windings (30, 31) comprises a conductor surrounded by a  
15 first semiconducting layer, said first semiconducting layer is then surrounded by a  
layer of fixed insulation, said first layer of fixed insulation is then surrounded by a  
second semiconducting layer.

16. Power storage system according to any one of the preceding claims,  
20 **characterized in**

that said rotor (24) comprises a first core (32), a second core (33) as well as a  
third core (34), the first winding (30) of the stator being arranged between said first  
(32) and said second (33) core and the second winding (31) of the stator being  
arranged between said second (33) and said third (34) core.

25

17. Vehicle provided with a power storage system according to any one of  
claims 1–16.

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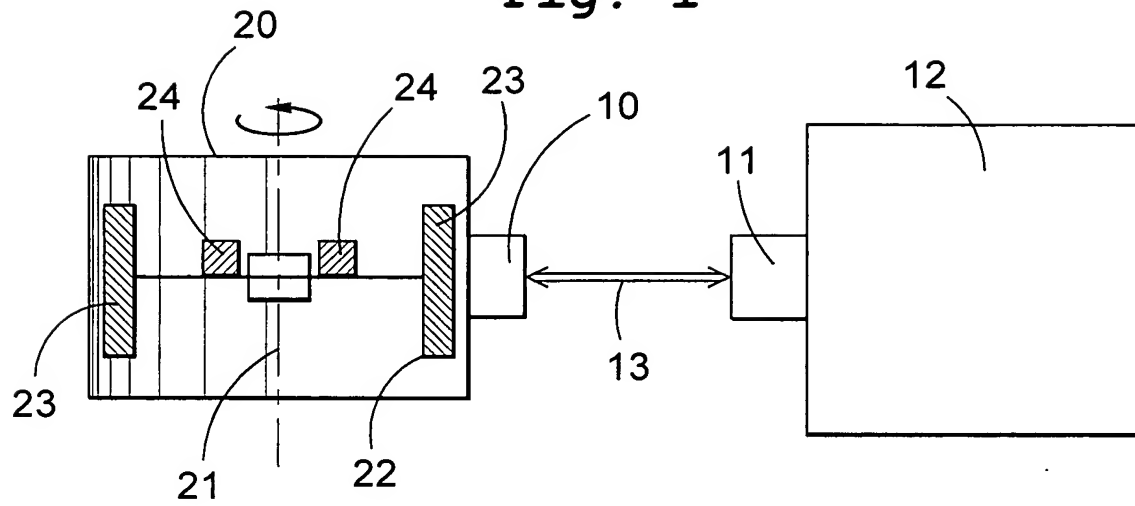
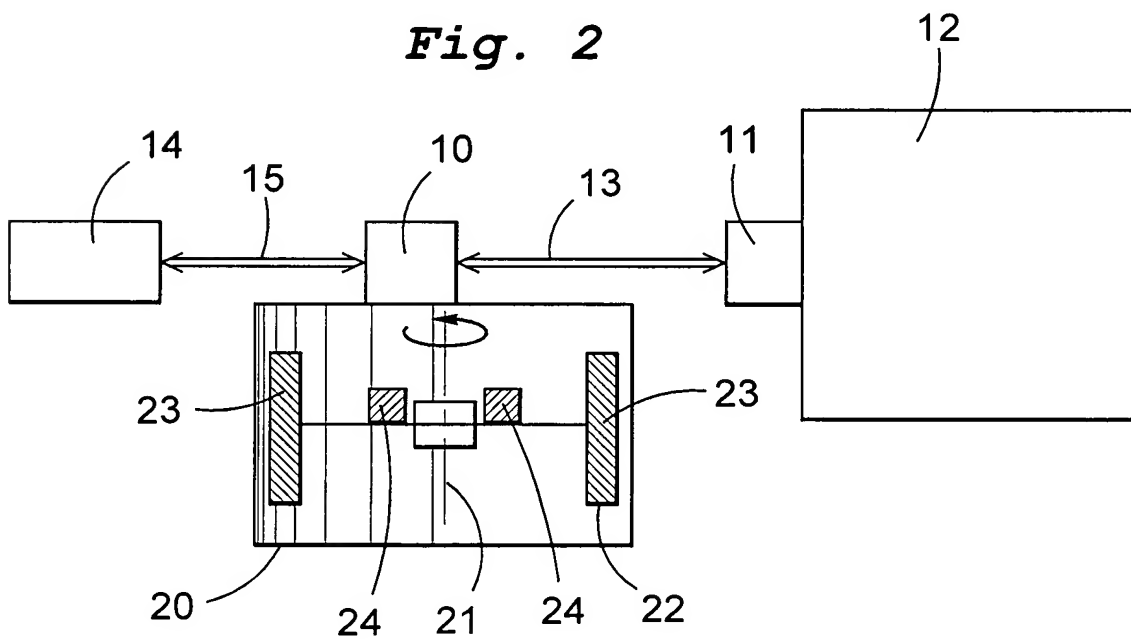
## ABSTRACT

The invention relates to a power storage system intended to transmit power to and from a driving system of a vehicle. A power storage having a stator provided with two windings and at least one rotor provided with a magnetic-flux generating device is comprised. The rotor is connected to a flywheel intended for storage of energy. The two windings of the stator are arranged for high and low voltage, respectively. The power storage is arranged to transmit power to and from the electric apparatus as well as store energy transmitted from the electric apparatus in the flywheel.

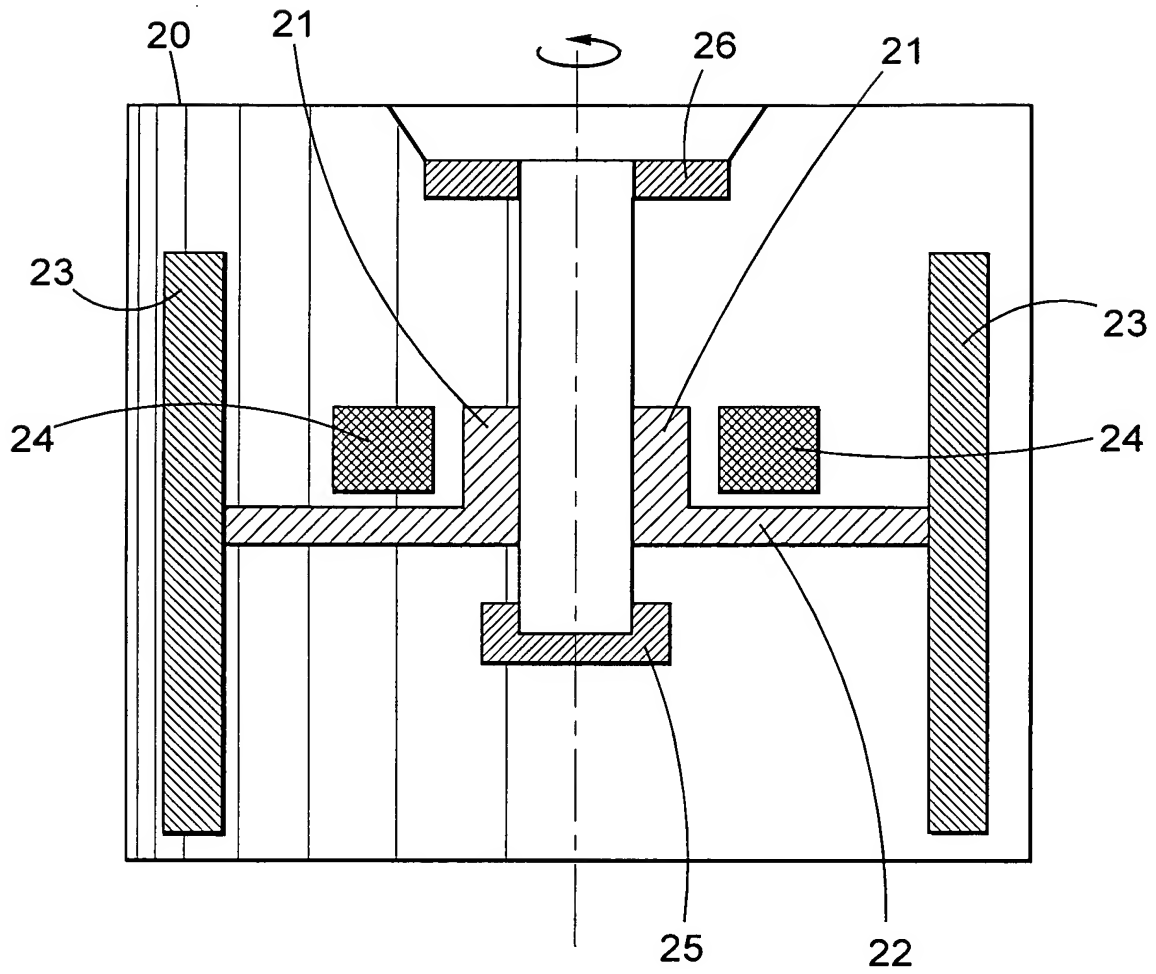
(Fig. 2)

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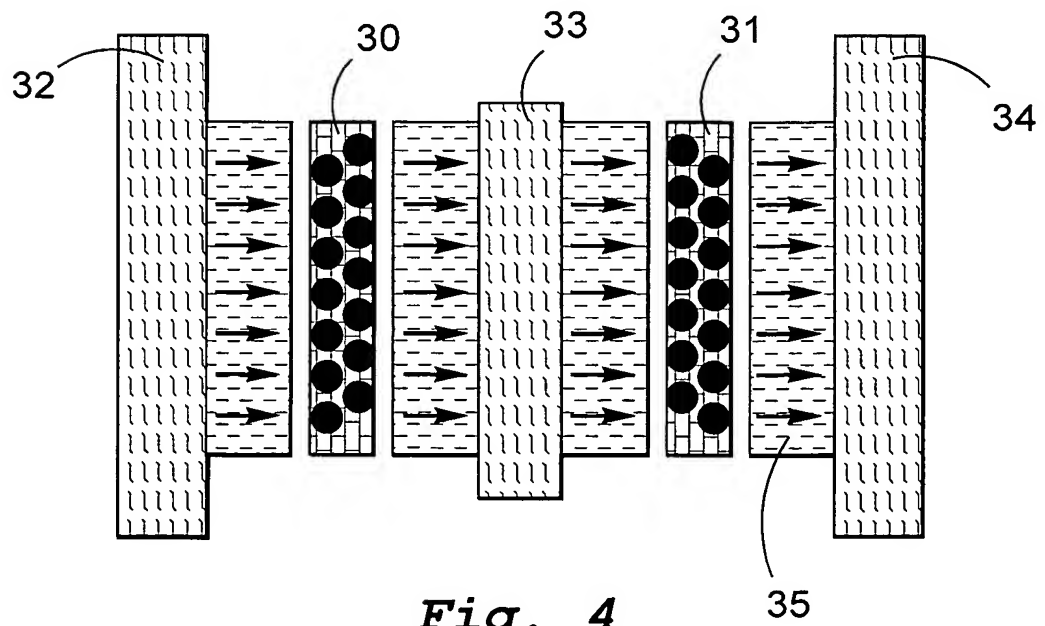
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*Fig. 1**Fig. 2*

2/2



*Fig. 3*



*Fig. 4*